OBSERVATION OF TRAVEL BEHAVIOR BY IC CARD DATA AND APPLICATION TO TRANSPORTATION PLANNING

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ABSTRACT:

So far, there have been many attempts to observe travel behavior of people in detail for transportation planning and ITS. One of the promising tools is IC card carried by people. The IC cards as bus tickets (bus smart cards) were introduced in March 2007 in Kanto area in Japan, and the bus smart cards have been in widespread use. The records of the bus smart card data are more than 38 million a month, and can represent the travel behavior of people. In this study, system of the bus smart card data collection in Japan is introduced, and the enormous bus smart card data is visualized for grasping the current transportation situation in the area of interest. In order to establish application of the bus smart card data to transportation planning, plausible analysis methods with the detailed travel behavior of people acquired by the bus smart card data are developed. For utilization of the bus smart card data, a method of converting bus smart card data to travel time and bus trip data is developed. The converted empirical data is applied to origin-destination analysis, and average of bus travel time estimation. By using the average bus travel time, relationship between the travel time and traffic congestion are analyzed. Additionally, an integration method of the bus smart card data with probe data is investigated. The integrated empirical data is applied to traffic monitoring, and extraction of obstructive factor for traffic flow.

1. INTRODUCTION

So far, there have been many attempts to observe travel behavior of people in detail for transportation planning and Intelligent Transportation System (ITS). One of the promising tools is IC card carried by people. The IC cards as bus tickets (bus smart cards) were introduced in March 2007 in Kanto area in Japan, and the bus smart cards have been in widespread use. The number of people who use the bus smart cards is around 20 million per month, and the records of the bus smart card data are more than 38 million per month, and can represent the travel behavior of people.

The IC card data of public transportation have been applied to transportation planning studies. Studies on the IC card data are under development. The examples of the studies are understanding of transport phenomena, utilization for traffic survey, estimation of traffic demand, and so on.

For understanding of transport phenomena, a data mining method for public transport user behavior was developed with 2.5 million people's IC card data (4 months). According to the mining method, the user behavior patterns were divided into 4 groups (Agard *et.al.*, 2006).

IC card data can be utilized as a means to traffic survey. A new traffic survey method combining interview and IC card data was proposed, and the method was applied to characteristics analysis of public transport user in Otawa (Chu *et.al.*, 2009).

In the estimation of traffic demand, origin-destination data (OD data) is used. For creating the data, IC card data can be used. By integrating household travel surveys results and IC card data, user characteristics in various routs and time, and OD distribution characteristics were analyzed. Through the analysis, applicapability of the IC card data to traffic demand estimation were discussed (Trépanier *et.al.*, 2009). IC card data also were used to monitor trend of transportation use. The IC card data were compared with traffic surveys (index of passenger miles and unlinked trips etc.) by New York City Department of Transportation (Reddy *et.al.*, 2009)

Moreover, IC card data were used for analysis of bus transfer characteristics in West Yorkshire (Bagchi and White, 2004). Not only bus transfer but also multi-modal transfer (from subway to bus, from bus to subway, and from bus to bus) were analyzed in London, and then number of trips of public transportation and rate of transfer were estimated (Seaborn *et.al.*, 2009).

Thus, studies concerning of IC card data has started, the number of analysis with the IC card data can be expected to increase.

In this study, system of the bus smart card data collection in Japan is introduced, and the enormous bus smart card data is visualized for grasping the current transportation situation in the area of interest.

2. BUS SMART CARD DATA

2.1 Utilization Trends of Bus Smart Cards

Private railroad and bus companies in the Tokyo metropolitan area introduced smart cards in March 2007. The smart cards can be used in both private railroads and buses. There were 23 private railroad companies and 31 bus companies (74 service offices and 4500 vehicles), which introduced the smart cards, and 15 million cards have been published (April 2010).

Figure 1 shows the number of card holders, times of card usage, and total times of card usage. The times of cards usage were totally 6.6 million times (0.2 million times a day) at start period. In 2010, the number of card holders is still increasing, there are 2 million times of card usage per day on average, 40 million times per month.

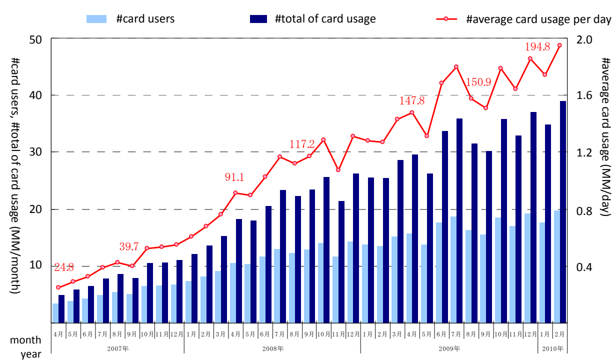


Figure 1. Utilization trends of the bus smart cards

2.2 Bus Smart Card Data

The bus smart card data consist mainly of ID, and mobile history (getting on/off bus stops and getting on/off time), and also include travel and stopping time of the bus, bus information (line ID, travel route, and number of buses), bus stop information (bus stop ID and longitude/latitude). By combining these data, number of getting on/off people at a bus stop, number of passengers between bus stops, OD data between bus stops can be generated.

In order to establish application of the bus smart card data to transportation planning, traffic monitoring, ITS, and so on, plausible analysis methods with the detailed travel behavior of people acquired by the bus smart card data are needed. For utilization of the bus smart card data in analysis of transportation planning, a method of converting bus smart card data to bus travel time and number of passengers between bus stops is developed.

When a bus smart card is touched to an in-vehicle reader (the timing at getting on/off), card ID and time are recorded. The time is considered as the passage time of the bus stop. By using the passage time, the travel time between the bus stops can be calculated (Figure 2). In the case of multiple passengers, the time of the first passenger's data is considered as arrival time and the time of the last passenger's data is considered as departure time. Since stopping time can be calculated from the arrival and departure time, the stopping time is excluded from the travel time. Additionally, the travel time between bus stops can be converted to travel time between intersections with travel route data and digital road maps to make transportation analysis easier. By counting the number of the bus smart cards, number of passengers can be acquired.

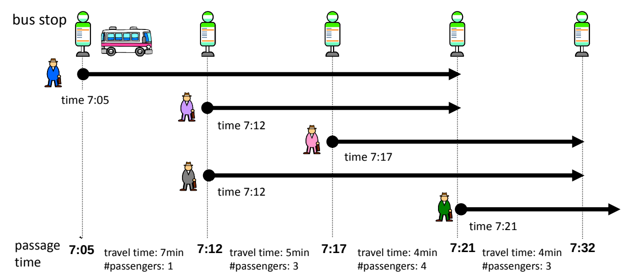


Figure 2. Travel time and number of passengers using bus smart cards

3. APPLICATIONS

The converted empirical data is applied to congestion spots analysis and improvement planning of bus stops. The area of interest is Saitama City, in where bus smart cards have been in widespread use.

3.1 Characteristics of Bus Smart Card Data

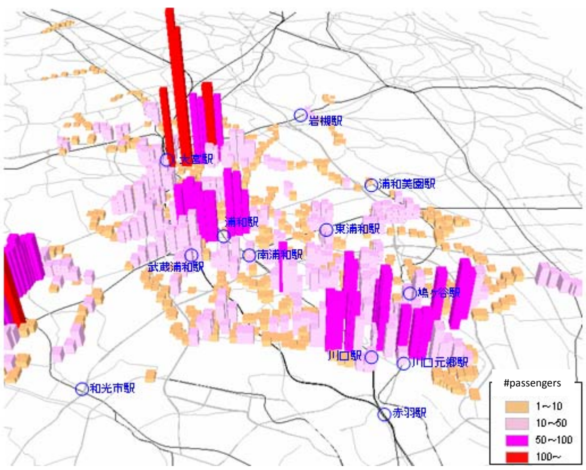
The number of passengers at/between bus stops and OD data between bus stops can be generated from the mobile history data in the bus smart card data.

For example, Figure 3 shows number of passengers at all bus stops during 10 minutes in a weekday and a holiday. Figure 4 depicts time series data of number of passengers in a day. These figures can help to understand the traffic situation.

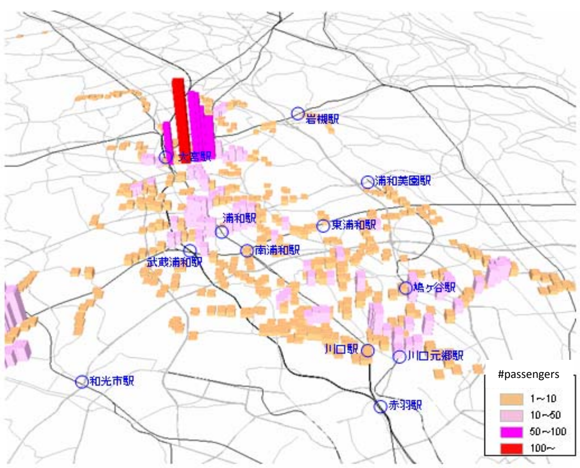
Additionally, the relationship between frequency of bus use and weather can be analyzed using the mobile history. Generally speaking, people who walk or use bicycles in fine days shift to use buses in rainy days. By using data for a one month period (October 2009), the relationships were analyzed. Figure 5 shows the relationship between number of passengers and precipitation amount. Especially, the numbers of passengers are superior in rainy days. Figure 6 shows composition ratio of frequency of bus use in fine and rainy days. In weekday, ratio of low frequency users increases from fine day to rainy day. It implies that many people use bus only rainy day. On the other hand, in holiday, the frequency use is almost same between fine and rainy day. It is considered that many people use bus in only holiday. Since the ratio of captive and choice can be understood through this analysis, the result will be expected to contribute analysis of relationship between fare and frequency.

3.2 Congestion Spot Analysis

Grasping congestion spot from the view of public transport with objective data is required to determine priority level of road maintenance and improvement. The bus smart card is suitable for the request.

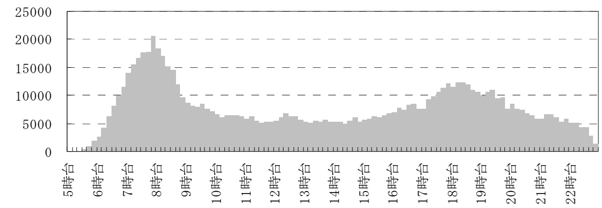


(a) Weekday

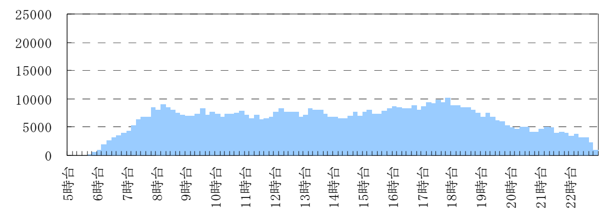


(b) Holiday

Figure 3. Number of passengers



(a) Weekday



(b) Holiday

Figure 4. Time series data of number of passengers

Bus traveling speeds are overlaid to ordinary congestion spots (Figure 7). The ordinary congestion spots are determined by private car traveling speed. Figure 8 shows congestion time at intersections (above) and bus traveling speed on average at

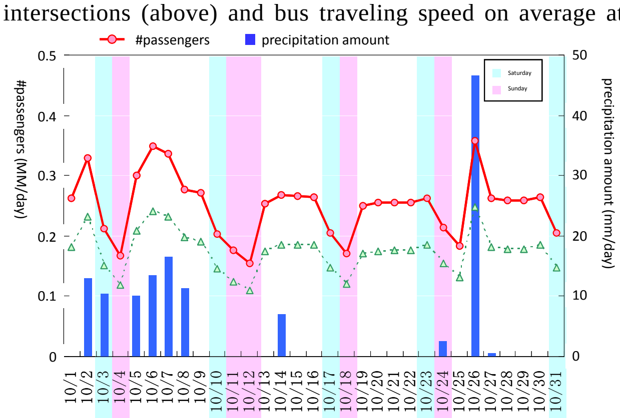


Figure 5. Relationship between number of passengers and precipitation amount

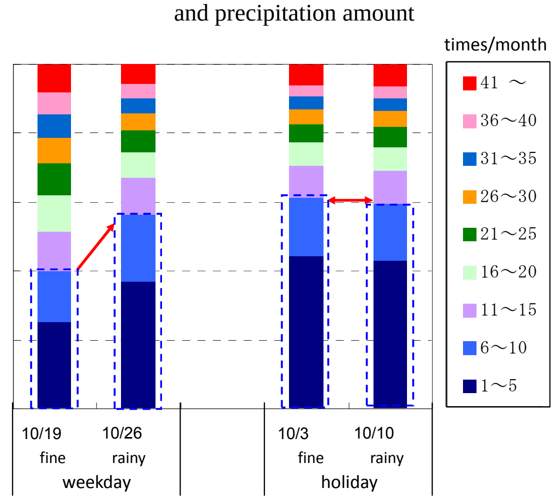


Figure 6. Relationship between frequency use and weather

intersections (below). The bus traveling speed was calculated by using average speed in a day during 11 day in each intersection. The ranks of congestion intersections are quite deferent between ranks based on private car data and bus smart card data. By considering the bus smart car data, more appropriate maintenance planning in the sense of public transport can be conducted.

3.3 Improvement Planning of Bus Stops

Road maintenance and improvement have been restricted because of financial difficulties in Japan. In such situation, public mobility improvement became important policy issue. Public mobility is affected by bus stop construction and maintenance. For example, inadequate bus bay raise problem of traveling performance degradation, because congestion occurs after stopping bus. When such type of bus stops is extracted by using bus smart card data, more effective and plausible selection of bus stop to be constructed and maintained among many bus stops can be conducted.

For the application, an integration method of the bus smart card data with probe data was investigated. The integrated empirical data was applied to traffic monitoring, and extraction of obstructive factor for traffic flow.

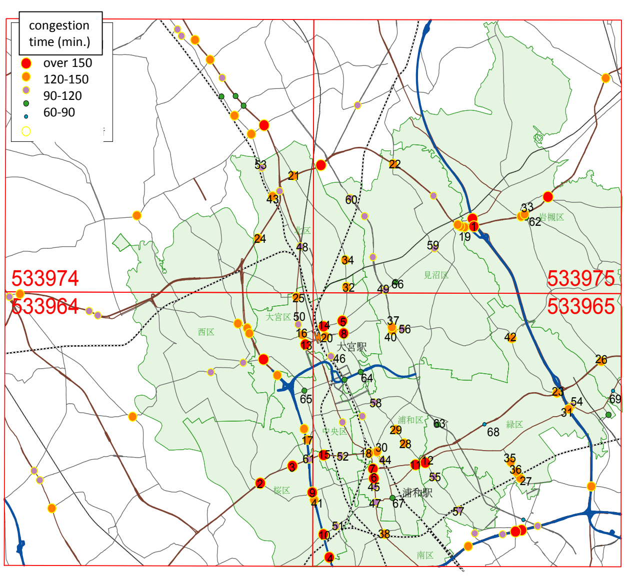


Figure 7. Bus traveling speed and congestion spots

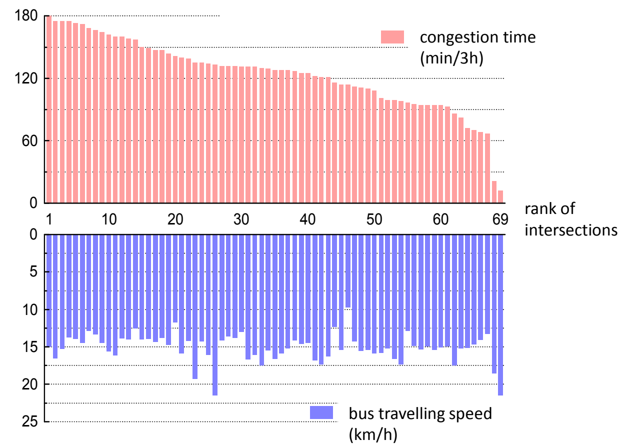


Figure 8. Rank of congestion intersections, congestion time, and bus traveling speed

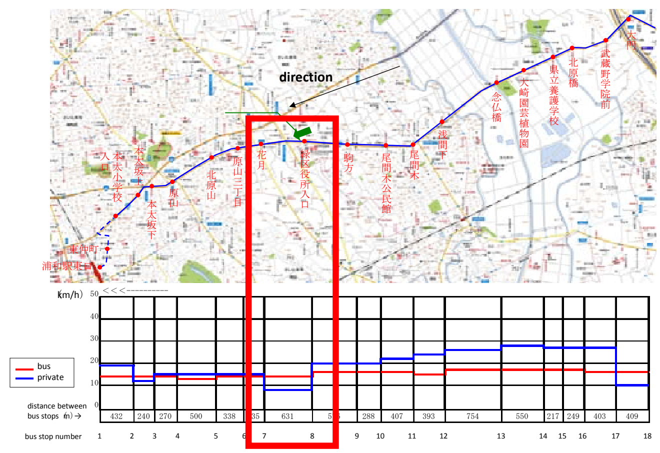


Figure 9. Comparison between traveling speed of bus and private car

Main route in Saitama City were set as area of interest. Because the probe data of private car is organized digital road map links, the data were converted to the data based on bus stop links. In Figure 9, red line denotes bus traveling speed and blue one private cars. On the link between bus stop number 7 and 8, traveling speed of private cars are much slower than one of bus. This means that the congestion occurs after stopping bus because of inadequate bus bay.

4. CONCLUSIONS

This study proposes use of bus smart card data for observation of travel behavior and applications of transportation planning. To be specific, characteristics the bus smart card data are investigated, and then relationships between traveling time and traffic congestion, and integrated data of the bus smart card data with prove data are analyzed. Through the application to Saitama City data, the significance of the proposal are confirmed.

However, the bus smart card data is just sampling data. All passengers cannot be tracked with the data. Additionally, attribution of the people like ages cannot be acquired. These points are limitation of the data.

As a further work, bus stop construction and maintenance planning will be continued through improvement of the analysis method with additional data. Finally, the proposed method will be reflected to actual policy decision stage.

REFERENCES

Agard, B., Morency, C., and Trépanier, M., 2006. Mining public transport user behaviour from smart card data. *Proceeding of 12th IFAC Symposium on Information Control Problems in Manufacturing-INCOM 2006*, CD-ROM.

Chu, K. K., Chapleau, R. and Trépanier, M., 2009. Driver-Assisted Bus Interview (DABI): Passive transit travel survey using smart card automatic fare collection system and its applications. *Proceeding of 88th Annual Meeting of the Transportation Research Board*, CD-ROM.

Trépanier, M., Morency, C. and Blanchette, C., 2009. Enhancing household travel surveys using smart card data?. *Proceeding of 88th Annual Meeting of the Transportation Research Board*, CD-ROM.

Reddy, A., A., Kumar, S., Bashmakov, V. and Rudenko, S., 2009. Application of entry-only Automated Fare Collection (AFC) system data to infer ridership, rider destinations, unlinked trips, and passenger miles. *Proceeding of 88th Annual Meeting of the Transportation Research Board*, CD-ROM.

Bagchi, M. and White, P. R., 2004. What role for smart-card data from bus systems?. Municipal Engineer 157, pp.39-46.

Seaborn, C., Wilson, N. H. and Attanucci, J., 2009. Using smart card fare payment data to analyze multi-modal public transport journeys (London, UK). *Proceeding of 88th Annual Meeting of the Transportation Research Board*, CD-ROM.